UNIVERSITI PUTRA MALAYSIA

EFFECTS OF WEAK ROCK GEOMECHANICAL PROPERTIES ON TUNNEL STABILITY

VAHED GHIASI

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By

VAHED GHIASI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

EFFECTS OF WEAK ROCK GEOMECHANICAL PROPERTIES ON TUNNEL STABILITY

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January 2012

Chairman : Professor Husaini Omar, PhD

Faculty : Engineering

Numerous tunnels are constructed in various parts of the world. Various technologies such as the Tunneling Boring Machine (TBM), New Austrian Tunneling Method (NATM), cut and cover method, and drilling and blasting method are used in order to aid tunnel constructions. In order to investigate the behavior of tunnels and to enhance these technologies, it is primarily important to investigate the issues pertaining to the soil and rock structure interaction. It is also of prime importance to study their impact on the tunnel system's performance. In engineering practice, geotechnical problems such as settlement and ground stability are not given due consideration in tunnel crossing constructions on the ground surface in urban areas. In order to deal with the challenges of geotechnology, full scale experiments may be performed. However it may not be feasible to conduct full scale experiments as it may be expensive.

The main purpose of this thesis is to evaluate the ground behavior in terms of deformation and strength parameters related to tunnel stability in different geomaterials such as weak rocks. This thesis has contributed vastly towards the understanding of the effects of tunnel structures on the geomaterials surrounding the tunnel and interaction between them. The main methods employed in this thesis are based on desk studies (theoretical investigation), laboratory tests, field investigations and the use of computer softwares. Advanced constitutive models were used in geometrical applications for numerical simulation of linear and non-linear, time-dependent and anisotropic behavior of soil and weak rocks. Unique procedures are required in order to deal with hydrostatic and non-hydrostatic pore pressures. These are needed as soil and rock are multi-phase materials. Although the modeling of the soil and rock itself is an important issue, many tunnel projects involve the modeling of structures and the interaction between the structures and the soil and rock. Numerical simulations with the Finite Element Method (FEM) and Finite Deferential Method (FDM) were conducted to analyze in order to evaluate the influence of stress on displacement and other factors in the process.

It is of prime importance to identify the mechanical properties of rock and soil. This is significant to assess the stability of tunnels as the design of support system is one of the most important steps in tunneling. Lack of knowledge of geo-mechanical and physical properties such as the mechanical behavior of the materials surrounding the underground or surface structure would make it impossible to offer suitable supervision, propose methods for an appropriate design, or predict risks with a reasonable degree of accuracy.

The current thesis contributes in various ways to enhance existing knowledge. Some of the significant areas are (i) the plan which has been developed for the design of tunnels; the plan for tunnel design and studding in rocks which contains the theoretical, and experimental investigations, including charts and graphs, of Karaj and North Water Convey Tunnel (NWCT) path and its stability analysis in Iran and electrified double track tunnel project between Ipoh and Padang Besar which is the longest rail tunnel project in Malaysia (ii**)** Evaluation of the squeezing potential of tunnels is presented in this thesis with significant results, (iii) Proposed method for evaluation of squeezing potential in rock tunnel which is Tunnel Instability Ranking(TIR), (iv) using numerical methods (FEM and FDM) to analyze the management of stability and hazards in tunnel construction. Another contribution is the studies regarding the modulus of elasticity and compressive strength in weathered granite, which is related to tunnel stability.

The results derived from the analysis indicate that tunnels in faulted regions are unstable and it is crucial to provide strong supports in these regions. The studies on the strength parameters and grain size of weathered granites revealed trends that show strength increases with decreasing grain size. It has been noted that with increased weathering, the modulus of elasticity decreases linearly with a decreasing uniaxial compressive strength.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai mementuhi keperluan untuk ijazah Doktor Falsofah

KESAN-KESAN GEOMEKANIKAL BATUAN LEMAH TERHADAP KESTABILAN TEROWONG

Oleh

VAHED GHIASI

Januari 2012

Pengerusi : Profesor Husaini Bin Omar, PhD

Fakulti : Kejuruteraan

Terdapat banyak pembinaan terowong yang dibina di seluruh dunia. Pelbagai teknologi seperti" Tunneling Boring Machine" (TBM), "New Austrian Tunneling Method (NATM)","Cut and Cover Method", menggerudi dan menggunakan bahan letupan digunakan untuk membantu dalam pembinaan terowong. Untuk menyiasat kelakuan terowong dan untuk menambahbaik teknoloji tersebut, adalah sangat penting untuk mengkaji isu yang berkaitan tanah dan struktur batuan Dalam amalan kejuruteraan, masalah geoteknikal seperti pemendapan dan kestabilan permukaan tanah tidak diberikan keutamaan yang sewajarnya dalam pembinaan terowong lintasan bersilang di kawasan bandar. Dalam mengatasi cabaran geoteknologi, eksperimen menyeluruh perlu dijalakan. Walaubagaimanapun kaedah ini mungkin tidak boleh dijalankan kerana projek ini memerlukan kos yang tinggi.

Tujuan utama tesis ini dijalankan adalah untuk menilai sifat permukaan tanah dari segi ubahbentuk dan kekuatan yang merupakan parameter yang berkait rapat dengan kestabilan terowong yang berbeza dari segi geobahan seperti batuan lemah. Tesis ini telah banyak menyumbang kepada cara memahami kesan dan tindakan geobahan keatas struktur keseluruhan terowong. Kaedah utama yang digunakan dalam tesis ini adalah berdasarkan kajian meja, ujian makmal, penyiasatan lapangan dan penggunaan perisian komputer. Model konstitutif lanjutan dibuat menggunakan aplikasi geometrical untuk proses simulasi numerikal untuk linear, bukan linear, pengaruh masa, dan sifat anisotropic tanah dan batuan lemah. Prosedur yang unik diperlukan untuk menangani hidostatik dan bukan hidrostatik terhadap tekanan liang. Prosedur ini diperlukan kerana tanah dan batuan adalah bahan berbilang fasa.. Walaupun model tanah dan butuan ini adalah satu isu yang penting, banyak projek pembinaan terowong melibatkan permodelan struktur dan interaksi struktur tanah dan batuan. Simulasi numerikal dengan menggunakan kaedah unsure terhingga (FEM) dan kaedah kebedaan terhingga(FDM) telah dijalankan untuk mengkaji terowong berkenaan dalam mengenalpasti kesan yang dihasilkan terhadap tekanan anjakan dan factor lain dalam proses ini.

Asas utama dalam proses ini adalah untuk mengenal pasti sifat mekanikal butuan dan tanah. Ini penting dalam menentukan kestabilan dan rekaan system sokongan .. Pengetahuan yang kurang dalam memahami geomekanikal dan kualiti fizikal seperti sifat mekanikial di sekeliling bawan permkaan atau permukaan menyebabkan susah untuk menawarkan penyeliaan kaedah yang sesuai.

Sumbangan tesis ini adalah dalam pelbagai cara untuk meningkatkan pengetahuan yang sedia ada. Sesetengah daripada kawasan projek terutamanya: 1)rancangan untuk membangunkan rekabentuk terowong; merancang untuk mereka bentuk terowong dan mencengkam batu yang telah dikaji secara teori dan melalui eksperimen termasuklah carta dan graf dalam mengkaji geomekanikal jism batu Karaj dan 'North Water Convey Tunnel'NWCT) dan analisis kestabilan di Iran dan projek pembinaan landasan berkembar terowong elektrik antara Ipoh dan Padang Besar yang merupakan projek rel terowong terpanjang di Malaysia. 2) Penilaian potensi untuk mengecilkan/ mengubah bentuk terowong yang dikemukakan dalam tesis ini bersama keputusan yang nyata. 3) mencadangkan kaedah untuk menilai potensi untuk mengecilkan / mengubah bentuk terowong batu yang merupakan gred ketidakstabilan terowong / Tunnel Instability Ranking(TIR), 4)menggunakan kaedah numerikal (FEM and FDM) untuk menganalisis cara pengurusan kestabilan dan risiko dalam pembinaan terowong. Antara sumbangan lain adalah mengenai modulus/ unit keanjalan dan kekuatan mampatan dalam mengubah bentuk granit/ batu keras yang berkait rapat dengan kestabilan pembinaan terowong.

Keputusan yang dikeluarkan dari analisis ini menunjukkan terowong di kawasan yang mempunyai sesar adalah tidak stabil dan adalah penting untuk memberi sokongan yang teguh di kawasan ini.

Kajian terhadap batuan granit terluluhawa bergantung kepada parameter-parameter kekuatan dan saiz butiran granit / batu keras, modulus keanjalan berkadaran secara linear dengan mengurangkan kekuatan mampatan unipaksi.

DEDICATION

This work is dedicated to my family members
who are always giving me encouragement
and support.

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Thank you MALAYSIA.

Vahed Ghiasi

10 Aug 2011

I certify that an Examination Committee has met on to conduct the final examination of **Vahed Ghiasi** on his **Doctor of Philosophy** thesis entitled "**EFFECT OF WEAK ROCK GEOMECHANICAL PROPERTIES ON TUNNEL STABILITY"** in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981.The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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Date: 30 January 2012

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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Date: 21 June 2012

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, or is not concurrently, submitted for any other degree at University Putra Malaysia or at any other institution.

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VAHED GHIASI

Date:

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